REVERSAL OF PHOTOTROPISM IN A PARASITIC WATER MITE

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Reversal in the phototropic response of certain animals sometimes occurs in the course of normal development and has been brought about in the laboratory by mechanical stimulation, change in temperature, change in light intensity, starvation, and chemical stimulation. In many cases the reversals produced artificially are apparently non-adaptive, or at least of no evident use to the organism. While working with certain parasitic water mites it was found that material from the host causes a reversal in the light response which is evidently of an adaptive nature. The reversal was studied in normal animals in directional light and also in animals blinded in one eye. The destruction of one eye brings about circus movements which are reversed by an extract of materials from the host.

The mite used in the study was *Unionicola ypsilophorus* var. *haldemani* (Piers). It lives between the inner and outer gills of the common fresh water clam or mussel, *Anodonta cataracta* Say, and is commonly called a parasite although it may be only commensal with the clam. The number of mites found in an individual clam varied from one to fifteen, the average for a large number of clams being 5.3 mites. Only very rarely were clams found without some mites present. According to Wolcott (1898) these mites seldom leave the host. However, they must do so at times, otherwise young clams would not become infested. During the course of the experiments specimens of *Anodonta* were kept under various conditions of light, temperature, and oxygen tension but on only two occasions were mites known to leave the clams. They seem to feed largely on the mucus from the gills and their presence in large numbers appears to increase the amount of mucus secreted.

When removed from the gills and allowed to remain in water from the mantle cavity, the mites are indifferent to directional light, wander aimlessly about the dish, and tend to cling to bits of mucus and gill. If washed and placed in fresh water free of material from the host they show a definite positive phototropism. Among a large number of individuals a few may remain indifferent to light but the majority show a strong photopositive reaction an hour or so after removal from the host.

When a number of mites are placed in an aquarium with a clam they soon find their way inside the clam. In one case forty-five mites were placed in a small aquarium with a single clam. The following day only two could be found free in the aquarium. The clam was opened and forty-eight mites were removed from between the gills, all but five of these having gained entrance to the clam over night.

The problem presented by the behaviour of the mites was to explain why they remain within the host although photopositive after removal, and how they are attracted to the host when free in an aquarium.

When a number of mites are placed in water containing pieces of gill they soon locate the gill, particularly if in the dark or in diffuse light. They tend to crawl into the gill by way of the cut edges or to collect under the pieces, there remaining quiet. This would seem to indicate a positive stereotropism. It is believed that a definite chemical stimulus directs the mites to the material from the host and that this attraction aided by a positive stereotropism keeps the mites within the clam even when a strong beam of light is projected into the mantle cavity.

During the early observations on the behaviour of these mites another interesting phenomenon was noted. Mites which were distinctly positive to light exhibited an immediate reversal to a photonegative state when transferred to a water extract of clam gill or to water from the mantle cavity of the clam. This reversal was at times only temporary but might last for a period of an hour or more. It was more pronounced and lasted longer if the mites had been out of the host for two or three days.

An experiment to show the effect of dilution of gill extract on the reversal of the light response illustrates the usual type of reaction.

Four pairs of gills were ground in a mortar with 20 cc. of distilled water. The mixture was centrifuged, the liquid decanted and filtered. 5 cc. of this extract, which for convenience may be called a 100 per cent solution, were placed in a small rectangular glass jar, 8 cm. long and 2 cm. wide. This was illuminated from one end with a beam of light from a 25 watt lamp at a distance of 15 cm., projected through an opening 2 cm. in diameter in an opaque screen. The light was reduced in intensity by interposing a sheet of tracing paper between the lamp and the jar. The end of the jar away from the light was covered on the inside with dull black paper coated with paraffin in order to prevent reflection of light. Ten photopositive mites were placed in the end of the jar nearest the source of illumination and their reactions noted.

For each dilution of extract a fresh lot of mites was used in order to avoid an accumulative effect.

Following are the results of using varying strengths of the original extract from 100 to 0.01 per cent:

100 per cent	10 mites immediately negative
50 per cent	9 mites immediately negative
25 per cent	8 mites immediately negative
10 per cent	8 mites immediately negative
5 per cent	5 mites immediately negative
2.5 per cent	6 mites negative (an obvious increase in the reaction time before the mites begin to move away from the light).
1.0 per cent	4 mites negative
0.05 per cent	2 mites negative
0.025 per cent	2 mites negative
0.01 per cent	0 mites negative

Only those mites which moved away from the lighted end of the jar and remained negative to light for an appreciable length of time were considered to have undergone a reversal in their response to light.

In control experiments handling and mechanical disturbance as well as the addition of small amounts of CO_2 were found to have no effect on the light response.

The reversal of circus movements of the mites confirmed the results obtained with directional illumination and offers a more striking demonstration of a change from a photopositive to a photonegative condition in an organism. Mites were blinded in the right eye by touching it with the point of a hot needle. The constant movement in circles toward the left or normal eye was sufficient indication that the blinding of the right eye had been successful. These animals showed remarkably uniform movements, travelling slowly, on ground glass, in circles with a diameter of 0.5 cm. When an extract of gill was added to the water near the mites, or when they were transferred to an extract of gill, an immediate reversal in the direction of circling would usually take place and the movement would be toward the blinded eye, indicating a change from a positive to a negative condition. Occasionally there would be failure to reverse or instead of complete reversal the movements would be at random.

An attempt was made to determine the nature of the substance in the gills which brings about the reversal in the light response and also exerts an attraction on the mites. Putrefaction at a temperature of 37.5° C. for a week was found to have no effect. At the end of this time the extract was as effective as fresh extract in causing a reversal.

Boiling for five to ten minutes likewise had little or no effect on the material which acts upon the mites. It is possible that decomposition products of the mucus or other proteins of the gills, which would not be affected by boiling or putrefying, are responsible for the reversal of the light response.

The organs concerned with the reception of the stimuli were likewise not determined. The removal of the labial palps at their basal joints in a number of mites had no apparent effect on the reversal or in the ability of these mites to locate and enter clams when free in an aquarium. As little is known concerning the chemical receptors in spiders and mites, it is difficult to say what centers are involved in the reversal.

Discussion

The behaviour of the variety of *Unionicola* which was studied seems to indicate a change from a primitive photopositive to a photonegative condition, due to a parasitic or commensal life. Negative phototropism assisted by chemotropism and stereotropism keeps the mites within the host. Upon removal from the influence of the clam, or material extracted from the clam, the mites revert to a photopositive state.

The rapid reversal from a photopositive to a photonegative condition when stimulated by extract of gill, or by water from the mantle cavity, is probably a central nervous phenomenon, and might be called a "conditioned reflex." Doubtless many parasitic animals become conditioned to stimuli from the host and show adaptive reactions quite different from their primitive responses.

Arey and Crozier (1921) investigated a case of change from independence of heliotropism to negative phototropism in *Onchidium*, a pulmonate mollusc, and their results are summed up in the following statement: "When tested apart from their specific normal environment the *Onchidia* are always negatively phototropic. In the natural state their movements are entirely independent of heliotropism . . . the simultaneous return to the nest on the part of the various members of a colony can be understood on the assumption of a 'reversal of inhibition' brought about by substances derived from materials while feeding." This case, while not identical with that described above, does indicate an effect of some substance in the food or in the environment on the light response of an animal.

Cole (1922–23) investigated the light response of *Limulus* and found that it might be modified by (*a*) fright, (*b*) hunger, (*c*) stereotropism, (*d*) photokinesis, and (*e*) unknown stimuli. He states: "It becomes clear after observing *Limuli*, however, that they are fundamentally and primitively positive to light, but that many factors may modify or mask the phototropic reaction."

Stier (1926) studied a case of reversal of phototropism in *Diemyctylus,* the spotted newt, and found that negative phototropism is characteristic of animals from which food has been withheld, while feeding reverses the response.

Summary

1. The water mite *Unionicola ypsilophorus var. haldemani* (Piers), living between the gills of the fresh water clam *Anodonta cataracta* Say, shows a positive reaction to light after removal from the clam.

2. An extract of the gills, or water from the mantle cavity of a clam, will cause a reversal to a photonegative state.

3. This reversal may be considered adaptive, for, aided by a positive chemotropism and stereotropism, it enables the mites to enter and remain within the host.

4. The phenomenon due to the parasitic life may be described as a "conditioned reflex"; the positive response to light being primitive and the negative response more recently acquired.

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